Satyajit Behari

Curriculum Vitae

Fermilab
P.O.Box 500, MS 318
Batavia, IL 60510.

Tel: **(630) 840-8607**
Fax: **(630) 840-2968**
E-mail: **behari@fnal.gov**

Professional Experience

- 2012 – present: Guest Scientist, Fermilab.
- 2001 – 2011: Associate Research Scientist, The Johns Hopkins University, Baltimore, MD.
- 1999 – 2001: Center-of-Excellence Research Fellow, Institute of Particle and Nuclear Studies, KEK, Japan.
- 1997 – 1999: Research Associate, National Central University, Chung-Li, Taiwan.
- 1996 – 1997: Research Associate, Institute of Physics, Bhubaneswar, India.

Education

- 1993 – 1996: Ph.D. in Physics, Saga University, Japan.
  Dissertation: "Observation of the Color Coherence Effect in Sub-jet Multiplicity of Three- and Four-jet Events in e^+e^- Annihilations at TRISTAN."
  Advisor: Prof. A. Murakami
- 1989 – 1991: M.Sc. in Physics, Ravenshaw College, India.
- 1986 – 1989: B.Sc. in Physics, Stewart Science College, India.

Research Experience

- **09/2011–09/2012** Co-Convenor of the CDF B Mixing, Lifetimes and CP Violation group, which later evolved into the B Analysis group. Heavy flavor physics has traditionally been a strong component of the CDF physics program since RunI. In Run II, equipped with a unique displaced vertex trigger, CDF has produced many landmark B physics results and has emerged as a world leader, surpassing the precision of B factory measurements on several occasions. I was appointed as a co-convenor of the B Mixing, Lifetimes and CP Violation group which in 2006 coordinated the B_s mixing discovery analysis and with growing data sample has produced a plethora of CP violation measurements, including $\sin 2\beta_s$, the phase of CP violation in B_s mixing. After the end of Run II data taking there were several interesting analyses completed in 2012 using the full CDF Run II datasets, most notably an exciting 2.7σ deviation from SM of the difference of CP violating asymmetries in the neutral charm decays.

- **06/2012–09/2013** Along with 3 CDF physicists I have measured the D^0-$\bar{D}^0$ mixing phenomenon with the full CDF Run II dataset. Although charm mixing is predicted since the discovery of the charm quark in 1974, it took over three decades for the B-factory experiments and CDF (2008) to see its evidence. Conclusive observation of the process has emerged this year firstly from LHCb ($9.1\,\sigma$) followed closely by us ($6.1\,\sigma$). Both the experiments have searched for this rare phenomenon by measuring the time dependence of the ratio of decay rates for the Cabibbo-suppressed rare decay $D^0 \to K^+\pi^-$ to the Cabibbo-favored decay $D^0 \to K^-\pi^+$. The main difficulties in this analysis is in dealing with the signal and background modeling, and untangling the prompt production component from the B decay one. Despite the establishment of charm mixing the experiments still lack precision to discriminate between theoretical predictions. Future measurements at LHCb and SuperB factory are necessary to tell whether there is a deviation from SM and, if so, whether new physics is needed to explain the behavior. This work is published in Phys. Rev. Lett. 111, 231802 (2013)

= **07/2010–07/2012** I have searched for a standard model Higgs boson in $H \rightarrow W^+W^-$ decays with a final state signature of two leptons and missing transverse energy ($\not\!\!E_T$). The search is performed separately in 13 channels with diverse background compositions and hence requiring dedicated multivariate analysis techniques for background discrimination. As part of the high mass Higgs search group of about 15 CDF physicists, I have performed the search in the same-sign dilepton decay channel which can originate from the associated production of Higgs boson along with a W or a Z boson. The analysis discriminates against the dominant Drell-Yan and W+jets backgrounds coming mostly from a lepton with charge mis-measurement or a jet faking a lepton. Utilizing a Neural Network technique I have searched for a Higgs signal with masses between 110 and 200 GeV/c^2 and have evaluated the resulting 95% C.L. upper limit cross-sections with respect to the standard model expectation based on a next-to-next-leading-order (NNLO) calculation. Since the past two iterations using 7.1 and 8.2 fb^{-1} data samples, respectively, I have made many improvements to the background modeling and Neural Network optimization. In the final iteration of the high mass analysis with the full ($\sim$ 10 fb^{-1}) Run II data sample CDF excludes, at 95% C.L., mass ranges $148.8 \leq m_H \leq 175.2$ GeV/c^2. The same-sign dilepton analysis alone provides a sensitivity of 3.2 times the SM cross-section at the most sensitive higgs mass of 160 GeV/c^2. An article summarizing the final results and the analysis techniques developed and pioneered at the Tevatron, is published in Phys. Rev. D 88, 052012 (2013).

= **05/2008–07/2009** Co-Leader of CDF Run II silicon project. The CDF silicon detector systems were the most expensive and sensitive piece of equipments in the CDF detector and are critical components of CDF's physics reach. I have led a team of $\sim$20 experts who were responsible for all aspects of functioning and maintenance of the CDF silicon detector systems. In addition to coordinating day-to-day operations I recruited/trained on-call experts and had final authority on all decisions pertaining to the project. To maintain the group's expertise and minimize the workload on the experts it was necessary to restructure the group, automate the routine operations and undertake several crucial studies on detector performance, most importantly the effects of radiation aging. I led several studies and task forces appointed by the collaboration to mitigate the problems and acted as a point of contact for other collaborations seeking help with their detectors. The group's activities and results were regularly presented at international conferences. I am the corresponding author of a document, detailing this work, which is published in Nucl. Instrum. Methods A729 (2013) 153-181.
At the end of Run II data taking a month-long dedicated study was performed on the silicon detector. During this period the detector was warmed up close to room temperature and the effect of annealing on the irradiated sensors were measured. This is the first such study on an operating HEP detector and is published in Nucl. Instrum. Methods A743 (2014) 68-78.

= **02/2011–10/2011** CDF detector operations manager. Building on my experience in running the silicon project I acted as one of the CDF Operations Managers, during the final stretch of Run II data taking, who ensure efficient operation of the CDF detector and high quality data acquisition. The responsibilities during a week long shift rotation included overseeing and assisting data taking shift crew, conducting detector repair/maintenance accesses in the CDF collision hall in coordination with the Fermilab Beams Division and representing CDF operations in the weekly Fermilab all experimenters' meeting.

= **09/2009–10/2010** Monte Carlo Representative for the CDF B physics group. Monte Carlo techniques allow for modeling physics processes as well as various detector and trigger effects which influence data collection. A good knowledge of these key factors is crucial to the success of any physics program. As the Monte Carlo representative for the B physics group I led an effort to keep track of changes in the physics models in use (by their authors) and the changing detector and trigger environment of the experiment. As my most significant contribution, I ported the B physics Monte Carlo simulation package into a user-friendly common framework used by the rest of the physics groups of CDF. I continue to support this framework for the B physics group and have produced a large pool of generic B decay samples for background composition studies for current/future analyses.

= **05/2006-12/2009** Measurement of Λ_b lifetime using a displaced vertex trigger data sample. Measurements of B-hadron lifetimes are important probes for understanding QCD, especially the underlying Heavy Quark Effective Theory (HQET) which treats the heavy b-quark and the light di-quark system a similar way as a heavy nucleus

and a light electron make up a hydrogen atom. While HQET is successful in predicting the B meson lifetimes, its prediction of Λ_b lifetime suffered from a long standing disagreement with the experimental world average. I along with 6 co-authors used a 1 fb^{-1} data set, collected using CDF's unique displaced track trigger, to extract Λ_b lifetime in fully reconstructed $\Lambda_c\pi$ decays. Since the trigger sculpts the Λ_b decay time distribution it was a formidable task to perform this measurement, disentangling the trigger bias. Our novel Monte Carlo driven technique produced the single most precise measurement (to that day), in agreement with the HQET prediction, and paved the way for several other similar measurements from CDF. A paper containing this work is published in Phys. Rev. Lett. 104, 102002.

= **07/2005–05/2006** Partial reconstruction of B_s decays using a Topological Vertexing tool for B_s mixing. Supervised a JHU graduate student's (Reid Mumford) research work, adapted the *Topological Vertexing* algorithm developed at SLD, SLAC, for use at CDF. It inclusively reconstructs multiple displaced vertices from track intersections, desirable in any long-lived particle searches. Initially the tool was applied to improve B_s mixing sensitivity by including partially reconstructed events. Following the CDF discovery of B_s mixing with unprecedented accuracy we didn't pursue this analysis further. In 2008 the tool was used to search for the Higgs boson decaying to two long-lived neutralinos, based on an R-parity violating SUSY model.

= **07/2002–03/2004** DAQ expert for the CDF Run IIb silicon R&D project. Trends in radiation aging effects in the early period of Run II data taking suggested a need for upgrading the silicon detector systems for the high luminosity Tevatron run beyond 2004. As a member of a small group of physicists and engineers, I participated in R&D and fabrication of a new generation silicon detector for CDF Run IIb, called SVXIIb. Entirely managed assembly and testing of a component of the data acquisition (DAQ) system called Mini Portcard. As a key person in the DAQ team adapted the Java-based CDFVME software for use with the new detector system. A full scale prototype of the whole system was found to perform well beyond its design parameters. This work is detailed in Nucl. Instrum. Methods, A556, 459 (2006).

= **05/2001–06/2002,04/2004–06/2005** Study of B hadron decays to ϕX charm-less fully hadronic final states. In 2001-3 Supervised a JHU graduate student's (Robert Napora) research work and measured the relative branching fraction, BR($B_u \to \phi K$)/BR($B_u \to J/\psi K$), in an early Run II data set corresponding to 120 pb^{-1}. Since the signal mode predominantly proceeds through the $b \to s$ penguin process it allows for a test of physics beyond Standard Model, if exotic particles participate in the loop.
In 2005 using a 355 pb^{-1} data sample studied various rare (charm-less) B decay modes which involve a ϕ resonance and a $V0$ particle (K_s^0 or Λ^0). These decay modes mediate through $b \to s$ FCNC transitions and help constrain contribution from new physics. Didn't see a statistically significant signal. However, the analysis procedure was approved by the hadronic B physics group for application to a much larger dataset in future.

= **08/2000–04/2001** Reconstruction of CP eigenstate decays of B mesons to a χ_{c1} for $\sin 2\beta$ measurement. One of the major goals of Belle(KEKB) and BaBar(PEPII) B-factory experiments was to measure/establish CP violation in the B sector. Using a 6 fb^{-1} data set collected using the Belle detector performed analysis of $B \to \chi_{c1}K(K^*)$ decays, with emphasis on the neutral modes involving a K_s^0 or a K^{*0}, where the χ_{c1} decays to $J/\psi\gamma$. Both these modes are CP eigenstates which contributed to the subsequent measurement of the CP violating phase, $\sin 2\beta$.

= **04/1999–02/2000** Event time determination for Belle track reconstruction. The work involved development and implementation of e^+e^- event occurance time algorithm for the Belle experiment. This was used in the charge particle track fitting as an additional parameter (6 parameter fit) and achieved an improved resolution. The input timing informations were taken from a multi-wire proportional chamber (dE/dx) and a Time-of-Flight system. Developed several web-based online tools to monitor track quality variables during the initial data taking.

= **09/1998–03/1999** Physics simulation of $b \to s$ penguin decay modes at Belle. As a member of the National Central University, Taiwan, group in the Belle Collaboration (KEK) I carried out physics simulation studies of several charmless rare decay modes of B mesons, which proceed via a ϕ resonance. This work assessed the

physics potential of the Belle detector for these rare decays, before it became operational.

= **10/1997–08/1998** Measurement of hadronic structure functions in the 3-prong τ lepton decays via the $a_1(1260)$ resonance with L3 (LEP) data. As a member of the National Central University, Taiwan, group in the L3 experiment, analysed Z peak data collected by the L3 detector, being stationed at CERN, Geneva. It involved a feasibility study of a hadronic structure function measurement in the 3-prong τ lepton decays via the a_1 (1260) resonance. The results were in agreement with those by the other 3 LEP experiments. However, they suggested that the L3 data is not sensitive enough to produce a statistically competative result.

= **05/1996–10/1997** R&D for a hadron-outer calorimeter for the CMS (LHC) detector. As a member of the India-CMS collaboration, participated in the R&D and fabrication of a plastic scintillator calorimeter, for use in the CMS detector. The barrel hadron-outer calorimeter (HO-B) serves as a hadronic energy deposit tail-catcher and improves energy resolution of hadrons that punch-through the main CMS hadron calorimeter. Developed a PostScript based database browser to visualize various geometry elements easily and produce AutoLISP output for workshop technicians.

Research Guidance Experience

As a research scientist in the Dept. of Physics and Astronomy of the Johns Hopkins University, I have been continuously stationed at Fermilab for conducting my research which has given me a unique opportunity to interact with the leading scientists of the experiment on a regular basis and collaborate with them closely on various projects. One of my major roles in the JHU group has been to help out the students with their day-to-day research problems and supervise their work. This often involves highly interactive tutoring sessions, leading to training the students for further collaboration on research projects. So far I have supervised the work of 6 graduate and 4 undergrad students. In addition to the JHU group students I have also supervised the work of several students from other university groups while leading the silicon detector group and the B Analysis group.

Awards

- Recipient of the prestigious Monbusho (currently called Monbukagakusho) Scholarship between 1993-1996, offered by the Japanese Government for higher education in science and technology.
- Appointed as a Center-of-Excellence fellow between 1999-2001 in the Institute of Nuclear and Particle Studies (IPNS) of the Japanese High Energy Accelerator Research Organization (KEK).

Distinctions and Leaderships

- Invited speaker and contributor of review articles to numerous international conferences.
- Collaborative authorship to 510 papers in peer reviewed international journals. Primary authorship to over 20 CDF internal papers detailing research work performed (available upon request).
- Acted as the CDF B group Monte Carlo Representative and served as a co-convenor of the B Mixing, Lifetimes and CP Violation (B Analysis) group.
- Supervision of Ph.D. level research work, leading to graduation of the students. Participation in the institution level peer review of 4 research work for publication in refereed journals. Have been a member of several review committees (comprised of 3 CDF collaborators) responsible for overseeing internal review of research work prior to their publication.
- As a silicon power supply expert coordinated a massive repair project. Acted as a co-leader of the silicon detector project. Served as a CDF Operations Manager during the last stretch of Run II data taking.

- As part of public outreach activities, conducted guided tours of the CDF experiment for groups of students/researchers and delegates from Indian Ministry. Have delivered several invited public talks on Fermilab science in Indian schools/colleges.
- Member of Japan Physical Society (1993-1996), Taiwan Physical Society (1998) and the American Physical Society (2004 onwards).
- Have a good grasp of two international languages: Japanese and Mandarin, in addition to being fluent in English and at least 3 Indian languages.

Recent Conference Presentations

- *CDF results on $b \to s\mu\mu$ decays*, 7th International Workshop on the CKM Unitarity Triangle (CKM2012), University of Cincinnati, USA, 28 September - 2 October 2012.
- *Beyond SM and Flavor Physics from the Tevatron*, 44^{th} Annual Fermilab Users' Meeting, Fermilab, IL, 1-2 June, 2011.
- *Recent B Physics Results from the Tevatron*, Rencontres de Moriond QCD and High Energy Interactions, La Thuile, Italy, 20-27 March, 2011.
- *B Spectroscopy and Lifetimes from Tevatron*, The 2010 Hadron Collider Physics Symposium, Toronto, Canada, 23-27 August, 2010.
- *Longevity Studies in the CDF II Silicon Detector*, 2009 IEEE Nuclear Science Symposium, Orlando, FL, 25-31 October 2009.
- *Properties of Weakly-decaying Bottom Baryons, Ξ_b^- and Ω_b^-, at CDF*, Meeting of the Division of Particles and Fields of the American Physical Society (DPF 2009), Detroit, MI, 26-31 Jul 2009.

Computing Experience

I have worked in several computing environments, namely IBM/*TSO*, VAX/*VMS* and almost all Unix platforms. I have owned/maintained personal computers to facilitate code development in my research work, which involved custom software installation, O/S upgrade; and management of network and a multitude of other services. During the CDF Run IIb silicon upgrade project I acted as the primary system administrator of the PC cluster owned by the project. For carrying out my software tasks I regularly use UNIX/Linux shell scripting languages, Perl/Tk and JavaScript. Among others I am also good at PostScript, Python and Elisp languages. For detector calibration and beams collision related information manipulation/retrieval I regularly use highly complex Oracle DBs at CDF and for smaller projects I create/manage MySQL DBs.

For my research work prior to joining the Belle experiment I had mostly programmed in Fortran77 with a strong knowledge in C. For all my recent CDF work I have been extensively programming in C^{++}. The front-end for the CDF Run II DAQ system was Java based. I adpated it for use with the Run IIb silicon detector components. I am well versed with most of the software used in experimental high energy physics, mostly developed at CERN and other particle physics laboratories. Among these I have studied several leading Monte Carlo event generators and have modified them for using in my physics analyses. I have a working knowledge of the GEANT detector simulation package and have extensively used many others including CLHEP, CERNLIB, MINUIT, Mn_Fit, ROOT *etc.*

While working on various detector hardware projects I have developed and maintained device control softwares as well. For the CDF Run IIb silicon project I have written a set of Root-based GUI classes for manipulating, histogramming and web publishing the silicon test data. As part of this project I have also developed classes for automation of power supply control over GPIB bus. For the Run II silicon operations project I maintained the power supply control code which ran on a VME (Versa Module Europa) processor and used the CAENET protocol (by CAEN Inc.) to interact with the power supply modules hosted on a SY527 mainframe. I have developed and automated it while working as a silicon power supply expert.

Selected List of Publications

1. M. Stancari *et al.*, "CDF Run II silicon vertex detector annealing study", Nucl. Instrum. Methods, **A743** (2014) 68-78.

2. CDF Collaboration, "Observation of D^0-$\bar{D^0}$ Mixing using the CDF II Detector", Phys. Rev. Lett. **111**, 231802 (2013).

3. CDF Collaboration, "Searches for the Higgs boson decaying to $W^+W^- \to \ell^+\nu\ell^-\bar{\nu}$ with the CDF II detector", Phys. Rev. D **88**, 052012 (2013).

4. T. Aaltonen *et al.*, "Operational Experience, Improvements, and Performance of the CDF Run II Silicon Vertex Detector", Nucl. Instrum. Methods, **A729** (2013) 153-181.

5. CDF Collaboration, "Measurement of the Λ_b Lifetime in $\Lambda_b \to \Lambda_c^+\pi^-$ Decays in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV", Phys. Rev. Lett. **104**, 102002 (2010).

6. T. Akimoto *et al.*, "The CDF Run IIb Silicon Detector: Design, preproduction, and performance.", Nucl. Instrum. Meth., **A556**, 459-481 (2006).

7. CDF Collaboration, "Observation of $B_s^0 - \overline{B}_s^0$ Oscillations", Phys. Rev. Lett. **97** (2006) 242003.

8. S. Behari *et al.*, "CDF Run IIb Silicon Vertex Detector DAQ Upgrade", IEEE Trans. Nucl. Sci. **51**, 3047 (2004).

9. G. Cardoso *et al.*, "Polyimide and BeO Mini Port Card Performance Comparison for CDF Run IIb", IEEE Trans. Nucl. Sci. **51**, 2174 (2004).

10. Belle Collaboration, "Observation of large CP violation in the neutral B meson system", Phys. Rev. Lett. **87** (2001) 091802.

11. Y.Sugimoto, S.K.Sahu, N. Takashimizu, S. Behari, S. Kobayashi, S. Matsumoto, A. Murakami, "A lead-scintillating fiber calorimeter for the small angle region of the AMY detector at TRISTAN", Nucl. Instrum. Meth. **A385** (1997) 463.

12. S. Behari *et al.*, "Observation of the color coherence effect in sub-jet multiplicity of three- and four-jet events in e^+e^- annihilations at TRISTAN", Phys. Lett. **B374** (1996) 304.

- -

13. S. Behari, H.Ozaki and J.Suzuki, "Event Time Determination in Belle Tracking", Belle Note **347**, August 2000.

14. S.Behari and S.Dugad, "A Reference Manual for the CMS-HO Database with a PostScript Interface, Version-1", India–CMS Technical Note, July 1997.